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RESEARCH ON MAN-MACHINE PRODUCTIVITY
IN AVIATION AT HUMAN ENGINEERING RESEARCH
INSTITUTE OF HANGZHOU UNIVERSITY

by

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RESEARCH ON MAN-MACHINE PRODUCTIVITY IN AVIATION AT HUMAN ENGINEERING RESEARCH INSTITUTE OF HANGZHOU UNIVERSITY

Jin Wenxiong, Zhu Zuxiang, and Wang Jian

The Human Engineering Research Institute of Hangzhou University is a scientific research organization engaged in research on the interdiscipline between psychology and technology. In recent years, ergonomic research on the fundamental theories and applications of man-machine productivity, regarding aircraft instrumentation lighting, displays, and controls, warning signals, computer terminal displays, human reliability, human body measurements, as well as management and decision making was carried on.

Under the research institute, there are four laboratories: signal display and control psychology, man-computer system, workload and safety psychology and management psychology. In addition, a series of advanced instruments and equipment were installed, such as type 1996 ocular motion loci monitoring system, Macintosh II fx computer system, KX-600 graphics display and level display system, UBD photometer for spectral dots, and UV-210 FW spectrophotometer. Furthermore, the laboratory of industrial psychology of the institute was designated by the State Planning Commission and State Educational Commission as a specialized laboratory among the few specialized laboratories in China.

Research on Lighting Environment in Aircraft Cockpits

Cockpit lighting is lighting with specialized requirements. The evaluation standards are accuracy and reaction speed for interpretive reading of instruments, dark adaptation, visual fatigue, color scale discrimination, and comfort level; these standards are used to determine the indicators of chromaticity, color temperature, illuminance, and uniformity. For example, as regulated in the State Military Standards, Requirements and Test Methods of Basic Technology for Aircraft Cockpit Lighting, the maximum value on the illuminance scale in instrument and meter illumination is 6 cd/m^2; the minimum is 1.5 cd/m^2. When the institute ascertained these two parameters, they conducted the experiments on interpretive reading of illuminated instruments and meters, experiments on dark adaptation, visual fatigue experiments, experiments on lighting uniformity, and experiments on tolerance to intensive lighting.

The following aspects are also noted in research on cockpit lighting:

(1) determination of threshold value and optimal value of illuminance of lighted instruments and meters

Under dark-chamber conditions, let the test subject read interpretively instruments and meters at a designated distance. The illuminance of the lighted instrumentation is adjustable. Under different illuminance conditions, in the experiments the accuracy and reaction time of a test subject engaged in interpretive reading of instruments were recorded. The value at which the test subject just begins to make out the readings on the lighted instruments and meters is called the threshold value of instrumentation lighting. The value at which the test subject can accurately (without error) and quickly make interpretive readings of the scales on the lighted instruments and meters, is called the optimal value of instrumentation lighting.

(2) Determine the effect on dark adaptation due to lighting illuminance.

In a dark chamber, the test subject is asked to interpretively read the scales on instruments and meters with different levels of lighting and illuminance. After a given test time period, dark-adaptation instruments are used to measure the time from his fixation points to his locating the dark marks on the dark-adaptation instrument. In addition, the time period involved in reading the scales is compared with the time period in locating the dark marks. When the illuminance of the lighted meters and instruments is low, the time period required to locate tne dark marks is short. With higher illuminance of the lighting, the time to locate the dark marks also increases.

(3) Determination of chromaticity of lighting

By adopting instruments and meters illuminated by the same illuminance but different colors of light, let the test subject make interpretive readings. After a certain time, measurements are made by using a dark-adaptation instrument to record the time required to locate the dark marks. As shown by the results, the red light corresponds to the shortest time needed to locate the marks, next is the low-color temperature white light (1800 to 200K [sic]).

With respect to lighting illuminance, the following experiments were conducted at the institute: different illuminance and dark adaptation levels, interpretive readings of instruments and meters, visual sensitivity, visual fatigue, and color discrimination. In lighting chromaticity, experiments were performed on different wavelengths of red light and different color temperatures of white light. As concerns lighting uniformity, experiments were conducted on visual productivity in a uniformly-lit environment in the range between 1:1 to about 50:1. These experiments profoundly expose the regularities between reactions in physiology and psychology for Chinese subjects under lighting conditions; thus, scientific evidence is provided to verify the cockpit lighting schemes of the new-generation interceptors, and for engineering design and regulating of aircraft lighting standards.

Research on Overall Graphic Presentation of Cockpit Information

In flight and during combat, flight personnel rely mainly on visual paths to obtain information inside and outside the aircraft. However, large amounts of information inside and outside an aircraft are available to the flight personnel. For example, in the F-18 cockpit, on one level display and three downward displays there are a total of 62 images, and 675 abbreviated symbols (177 of these symbols are displayed in four sizes) with a total information content of more than 1000. In flight and during combat, the physical and mental demands on a pilot are undeniably severe. In this respect, productivity experts have proposed many methods. For example, there are different ways of presenting this large variety of information, using different shapes and different colors; measures of shape encoding and color encoding are used for different symbols. Thus, the flight personnel can operate at the optimal interpretive rate when discriminating information.

At the institute, based on the living habits and cultural background of the Chinese subjects, as well as the demands of end-user departments, comparison experiments were conducted on symbols conveying the same information (consistent with international usage) but represented by different shapes, as shown in Fig. 1. In Fig. 1, the fuselage standard symbols have two styles of representation by shape, A and B. Under the conditions of strictly controlled environmental lighting and observation distance, the authors simulated the working environment of an artificial horizon instrument in an aircraft. Two different fuselage fundamental symbols are overlapped onto the background of the elevation or dip lines in the artificial horizon instrument, to form multiple images. During test on subject activity procedures during flight, some image is randomly displayed. The test subject is required to immediately, at his fastest reaction, read out the dip or elevation angle indicated by the fuselage fundamental symbols; the reaction time for the interpretive reading is recorded. In the experimental results, the reaction time for interpretive reading is shorter for A than B. The difference is obvious.

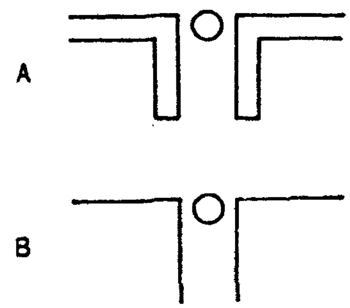

Fig. 1

On the presentation approach of information symbols, there should be a scientific basis on whether the concentrated or scattered presentation is the best, on whether the presentation should be before or after, and also the presentation sequence of the symbols. As shown by research at the institute, whether an image combination is rational and whether different positions of symbols in the image are more important than the symbol design as affecting interpretive reading was done.

Factors affecting the results of image interpretive reading are also illuminance, color scale, and contrast of symbol display, as well as symbol size and line thickness, among other factors. In research studies at the institute, such as the relationship among CRT letter symbol illuminance, background illuminance, and contrast; research on CRT displayed color encoding; research on visual productivity of terminal displayed color and visual frequency display; and research on effects of Chinese character font, character height, and stroke thickness on interpretive reading results in electro-optical aircraft displays; these researches provide parameters of man-machine productivity suitable for Chinese subjects with regard to specifying related standards and engineering design in China.

Research on Signal Displays in Cockpit

In flight combat, the status of various aircraft systems is communicated to flight personnel by a variety of signal displays. Since there are many systems and items of equipment in an aircraft, warning signals are quite numerous. For example, there are 455 warning signals in the cockpit of B747; there are 73 visual warnings, 54 indicator lights, and 6 tones for audible warning in an F-18 fighter. This information can be classified into three levels (warning, attention, and reminder), according to the degree of danger. For situations of danger to flight safety, the information should be immediately communicated to the pilot for immediate measures to be taken; these are warning signals such as engine afire. For factors that have a bearing on completion of a flight mission, or leading to the deterioration of system and equipment performance, this information should be immediately communicated to the pilot, but immediate measures need not be taken; these are attention-gaining signals, such as fuel gauge low. For this kind of information about working conditions and performance status of the systems and items of equipment related to flight safety, or the signals reminding flight personnel about routine operations, these are reminder signals, such as takeoff levelness. Warning signals of different levels and kinds can employ different colors, such as red for warning signals, and orange for attention-gaining signals.

Furthermore, different installation positions can be adopted based on different warning levels. For example, the warning signals are located at the center of the visual zone, and other kinds of signals are located at the margins of the visual zone, so that the pilot can quickly discover and understand the malfunctioning sites and situation for appropriate measures to be taken.

Fig. 2. By using the ocular motion monitoring system, research personnel are conducting studies on visual search and scanning modes

Experiments should be conducted on the rational classification of warning signals, lighting illuminance for optimal presentation results, and compatibility of signal lights and color of cockpit illumination. At the institute, the following experiments were conducted: research on appropriate illuminance on night displays of aircraft signal lights when illuminated with red and white light; research on the effect of discrimination results from illuminance with red, orange, and green signal lights with a strong background lighting; and research on engineering psychology on the presentation approach of visual warning signals and comparisons of visual results of aircraft signals display box in red, orange, and green colored symbols with white background under illumination of different intensities of high color temperature background lighting.

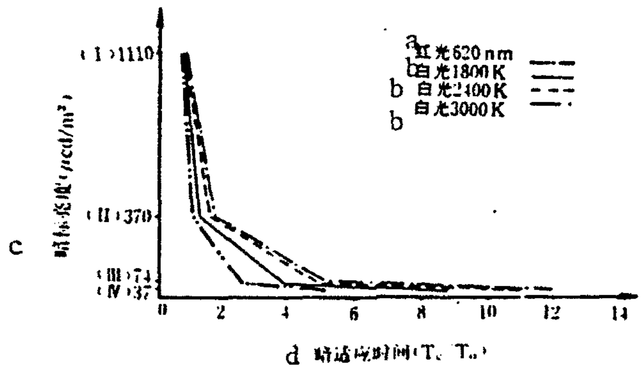

Fig. 3. Short-term dark adaptation curves for different light colors under conditions of 10 cd/m^2 of lighting on instruments and meters
KEY: a - Red light b - White light
c - Illuminance of dark mark d - Dark adaptation time

Synthesized voice warnings with computer simulation began to be employed in some aircraft abroad. At the institute the following research studies are underway: voice signal-to-noise ratio; instantaneous capacity for auditory comprehension of Chinese; pace of warning voice; and integration of auditory and visual warnings. Some completed experimental results provided scientific data for pause time between sentences and speaking pace as related in State Military Standards, Requirements on Basic Techniques of Warning in Aircraft.

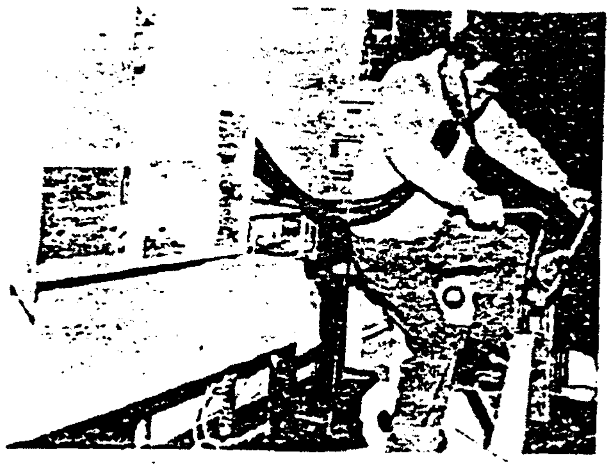

Fig. 4. Scientific research personnel being subjected to workload tests

Fundamental Research on Human-information Processing

Research on visual search and scanning modes

The advanced ocular motion monitoring system is used in this research. In the real-time operational process, the ocular motion loci, pupil changes, and other parameters are recorded in studying the properties and regularities of visual search and scanning activity.

Research on intermatching relationships between target color and background color

Channel capacity serves as the effective scale in conducting studies on the matching relationship between background color and target color in CRT color displays.

Research on evaluation indicators of psychological load

Under different conditions of operation and psychological loads, comparative experiments are made dealing with indicators of cardioelectricity, cardiac rhythm, cardiac pumping pressure, and urine levels of reduced adrenalin. In addition, comparative studies are conducted on physical loads of different weight, posture and work pace.

Research on finger stimulation time sequence and touch mode

By adopting a visual-touch transducer as the touch display apparatus, studies are underway on different fingers and sites by stimulating the left and right hands at different time intervals and different vibration modes; thus, parameters are provided for decision-making capability in order to understand the time sequence of vibration stimulation via finger touch.

Research on measurement of functional dimensions of the human body

Using advanced equipment for making human body measurements, systematic measurements are made of the sweep range of both upper limbs outstretched; in addition, studies are underway on the time during which the upper limbs are extended during coordinated eye-hand operations; thus system parameters are obtained for dimensions of human body functions (upper limbs) to be used as the basis for man-machine productivity in designing operational space and maneuvering equipment.

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